WARD

MEMORANDUM ON SOIL, CONTOUR AND DRAINAGE OF HUDSON COUNTY, N.J.

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OF

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BY

L. B. WARD, C. E.

With additional Notes relating to Sewerage Works.

PRIVATELY PRINTED.

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W. R. VIDAL, 34 BROAD STREET.

1878.

The preparation of this paper and its primary appearance, by request, in the annual report of the County Board of Health, grew out of the appointment, by the New Jersey State Sanitary Association, of a committee on the "Soil, Drainage, and Sewerage of certain sections of Jersey City, Hoboken, and Paterson, in their relations to the death-rate," of which the President of the Health Board and the writer were members.

The original memorandum has been revised, and is now reprinted, in a somewhat more complete form, with an appendix compiled from the recent instructive reports on the Improved Sewerage of Boston.

The present edition is intended for the use of the Sanitary Committee, and of others who feel a local interest in the drainage and sewerage of this portion of Hudson County.

JERSEY CITY, *March* 26, 1878.

ON THE SOIL, CONTOUR, AND DRAINAGE

OF HUDSON COUNTY.

The influence of geological strata and soils upon health, although recognized from time immemorial, has only within a few years been made the subject of careful statistical inquiry, both apart from, and in connection with, studies of the beneficial effects, as regards public health, due to the drying of the subsoil by drainage and sewerage works in towns and cities.

In all works of sewerage, in order to obtain their full benefit, it is necessary that provision should be made for the draining of the subsoil. The mere fact of carrying out such a system of works, and of being obliged to cut through various strata of a more or less retentive character, is naturally a means of securing, to a great extent, subsoil drainage, but results thus produced are somewhat variable, experience having shown that such works when first brought into operation, or during their construction, have had a greater effect in drying the subsoil, and in reducing the rate of mortality from phthisical disorders than has been maintained in after years. This may be accounted for from the fact that the drainage of the subsoil was more perfect before the complete consolidation of the earth contained in the sewer trenches than afterward. It is not safe then, among difficult geological surroundings, to depend solely upon the intersection of the strata for the subsoil drainage, and it must be admitted, that the absence of good natural advantages of soil and slope can never be quite remedied by the best artificial appliances.

As an illustration of the geological side of this question, fifty registration districts situated in the homogeneous tract comprised in the three contiguous English counties of Kent, Surrey, and Sussex, and embraced in one inquiry conducted by the medical staff of the Privy Council of Great Britain, were grouped into five classes of ten each, strictly in the order of the prevalence of death by consumption, an analysis having been made to see what proportion of the population in each group were living on pervious or on impervious soils, with the following results, beginning with the lowest death rate:

Prevalence of consumption as related to the character of the soil.

	DISTRIBUTION OF POPULATION	
	Percentage on Pervious Soils	Percentage on Impervious Soils.
Group No. 1	90.9	9.1
" No. 2	87.7	12.3
" No. 3	79.5	20.5
" No. 4	79.2	20.8
" No. 5	64 2	35 8

The following table shows the ratio in which deaths by consumption have been found to diminish in the towns named, consequent upon the prosecution or completion of improved drainage works; the statistics cover a number of years, and are given upon the authority which has been already quoted.

Sanitary results produced by lowering the level of subsoil water.

Name of Place.	Population in 1861.	Reduction in rate of Phthisis.	Reduction in total Mortality.
		Per cent.	Per cent.
Rugby,	7,818	43	2½
Ely,	7,847	47	14
Salisbury,	9,030	49	20
Banbury,	10,238	41	12½
Dover,	23,108	20	7
Newport,	24,756	32	32
Macclesfield,	27,475	31	20
Leicester,	68,056	32	4½

Average reduction in total Mortality, 12½ per cent.
Average reduction in death rate by Consumption, 33 per ct.

From the investigations in England first referred to, and from those made in Massachusetts, previously, by Dr. Bowditch, the general opinion as to the insalubrity of wet and retentive soils, and of those in which, for any reason, underground water is found at shallow depths, has received substantial confirmation, while the benefits resulting to the public health from the artificial removal of the subsoil water have been quite as distinctly proved. The conclusions reached are of such value as to introduce new considerations into plans of public drainage, as well as into the election of places for private abode. It is the purpose of this paper to discuss some of the physical and topographical characteristics of Hudson County, with regard to these considerations.

PHYSICAL OUTLINE.

The calculated area of land and water within the boundaries of Hudson County is 51 square miles; the extent of land surface being $44\frac{6}{10}$, and of water surface $6\frac{4}{10}$ square miles.

The extreme length of the county is $14\frac{1}{2}$ miles, measured in the general direction of north and south; its greatest width between the Hudson and Passaic Rivers is 7 miles—its least width, taken between New York Bay and Newark Bay across Bergen Neck, scarcely exceeds one-half mile.

The total extent of shore line bordering navigable tidal waters within the limits of the county, neglecting inlets and minor sinuosities, is 48 miles. The length of the shore line and the area of the land surface bear such a proportion to each other as should give an average length, for the whole county, of less than one mile for lines of direct drainage into tidal waters, did the contour of the ground generally admit of them. The tidal waters of the county are nowhere fresh or sweet waters, except in that part of the Passaic River which forms its extreme western boundary, and from which is taken, at a point just without the county limits, the water which is supplied to the cities of Jersey City and Hoboken.

The mean range of tide in these waters is as follows:

New York Harbor............	4.4 feet.
Newark Bay..................	4 8 "
Passaic River, at Newark.....	5 0 "

The Hackensack River by its position midway between the Hudson and Passaic divides the county into two peninsular areas, and by the depth and volume of its estuary, the peculiarities of its channel and banks, and the breadth and extent of its marshes, contributes important elements to the general topography.

The geological structure of the county has as a whole a gradual and regular inclination in a direction slightly west of south; this inclination shows itself in the general course of the rivers, in the contour of Newark Bay, and in all the leading topographical outlines, independently of the features of the transverse profile of the district.

The rocks underlying the county, and cropping out to a greater or less extent, are serpentine, trap, and sandstone. Gneiss also underlies a portion of the water front of Jersey City, but does not show itself above the level of tide.

Serpentine forms the promontory 100 feet in height, on the Hudson River at Hoboken, with an area of 30 acres; this rock is granular and porous in texture; absorbs surface water promptly, thereby greatly promoting natural drainage; transmits heat very slowly, but retains it tenaciously, forming a highly salubrious substratum.

Trap is an intrusive, igneous rock of close grain, impervious to water, and a ready conductor of heat; it is on these grounds an undesirable element in the geology of the county. It forms the ridge known as Bergen Hill and Bergen Neck, extending the entire length of the county. This ridge, which is the southern continuation of the Palisades, has at Guttenberg, near the northern boundary of the county, a width exceeding one mile, with a summit elevation of 260 feet; its width and elevation diminish with considerable regularity to the extreme southern end of the county at Bergen Point, where, being narrowed to one-half mile, it passes under the waters of Kill Van Kull. Midway between the points named the elevation is about 120 feet above tide.

The trap presents a vertical face to the east, and dips to the west, the prismatic joints of the rock being nearly vertical. The original summit of the ledge has been worn down and channelled, for a breadth of about 2,000 feet from its eastern face, by geological agencies, which have reduced it to an irregular tabular surface with rounded prominences and occasional rock-basins, the drainage of this portion of the ridge for its whole length escaping to the eastward by numerous ravines. The summit, wherever the ledge is not exposed, is overlaid by a tenacious, clayey, soil or earth, the product of the abrasion and disintegration of the rock itself. The western slope of the hill is covered throughout, to a considerable depth, by a deposit of loose drift consisting of gravel of foreign origin intermixed to some extent with the soil of the hill. The line of demarcation between the ledge, at the western brow of the hill, and the bank of loose drift resting against it, is said to have been long recognized in the experience of resident medical men as constituting a true sanitary boundary, restricting the prevalence of the worst forms of epidemic disease.

The population living upon the trap belt in this county, numbered in 1875 about 65,000, estimated as follows: on Bergen Neck, south of Jersey City, 6,000; in Jersey City, 44,000; in the northern portion of the county, 15,000.

Outside of the belt just described, and about one mile to the west of it, the trap appears on the bank of the Hackensack River at Snake Hill, a solitary knob of rock rising 175 feet above the surrounding marsh: the circumference of this outcrop is one and one-half mile.

Sandstone is the predominant rock of the county, though as a tangible substratum, it can only be observed to any large extent in the uplands at Secaucus adjoining Snake Hill, and in the ridge of high land immediately east of the Passaic River, their combined area amounting to between 6 and 7 square miles. The population inhabiting these uplands, and embraced in the towns or townships of Harrison and Kearney, and a portion of North Bergen, is estimated at 7,000 in all. In point of salubrity due to a capacity for readily absorbing moisture, the sandstone deserves to rank well as a substratum. The overlying red soil produced by the disintegration of the rock, has usually a sandy, but sometimes a clayey, character, the latter indicating shale below. The greatest elevation of the sandstone is attained at the Belleville Reservoir of the Jersey City Water-Works in the boundary line of Bergen County; the surface at this point is 150 feet above tide.

The extensive tide marshes on both sides of Bergen Hill, as well as the beds of the Passaic and Hackensack Rivers, and Newark Bay, are also underlaid by the sandstone; the trap is imbedded within the mass of this rock formation, the sandstone appearing as the inferior stratum on the Hudson River, and as an overlying rock on Bergen Neck.

Measurements taken from such maps as are available, give the following approximate areas for the principal topographical divisions of the county, viz.:

	SQUARE MILES.	
East of Hackensack River:		
Original upland	21.5	
Made land on Hudson River and New York Bay	1.0	
Meadows east of Bergen Hill	2 5	
" west " "	8.4	
		33.4
West of Hackensack River:		
Upland	4.4	
Meadow	6.8	
		11.2
Total area of land (about)		44.6

Recapitulation:

Total upland in the county	25.9
" meadow " "	17.7
" made land " "	1.0
" water surface within the county lines; in Newark Bay, Passaic and Hackensack Rivers	6.4
" area included in Hudson Co. (about)	51.0

The lands classed here as meadows include only salt marshes, or lands which have been in their primitive state subject to periodical overflow by the tides. Those west of Bergen Hill belong to the Hackensack meadows; their width from side to side of the valley is four miles, with a maximum depth of 90 feet, or more, to rock or hard bottom. The principal meadow east of Bergen Hill extends from Weehawken to Communipaw, a continuous distance of three and one-half miles, and has an average breadth of 2,000 feet, with a probable maximum depth of 100 feet.

The distribution of upland and meadow east of Bergen Hill is extremely irregular. A succession of six or more detached sand-hills and low ridges or bars of the same material, having an aggregate area of about two square miles, extends with unequal intervals from Castle Point to Constable's Hook along the original water front, or touching it; one only of these formations—the upland of Communipaw—adjoins the Bergen ridge; the others are, or were formerly, isolated in the tide marshes. A city population, in Jersey City, occupies the insular uplands of Pavonia and Powles Hook, the combined area of which exceeds 400 acres, to which may be added 100 acres of marsh lying between them, which has been converted into a partial upland by the disposal of surplus earth upon it, in the process of levelling the higher ground. The Hoboken upland has an area of 275 acres, 90 of which are built upon; a portion of the Communipaw uplands, in extent about 75 acres, has also been built over, forming a suburb of Jersey City. The population inhabiting the several areas named amounts, approximately, to 11,000 in Hoboken, and 55,000 in Jersey City.

Population has also spread itself from the uplands last described, over a certain extent of the adjacent marsh—9,000 upon an area of 35 acres in Jersey City, and 14,000 upon 140 acres of low lands in Hoboken.

The water front between Powles Hook and Hoboken, formerly a deeply indented shore line inclosing a body of shallow water covering 400 acres, has been advanced to navigable water of the Hudson River, by artificial additions to the shore. Land to the extent of 200 acres has also been reclaimed in the same manner from the waters of New York Bay in front of the Communipaw shore. The materials used to bring up the level of these lands to their present height above tide, have been silt dredged from the river bottom, and street gatherings from New York city; ordinarily a superficial layer of natural earth has been applied above these, as a matter of convenience, if not as a disinfectant. These lands are to a very small extent inhabited, or built upon, being in the main appropriated for railroad yards.

TOPOGRAPHICAL DIVISION OF THE POPULATION.

On uplands, east of Bergen Hill	66,000
" marsh, " "	23,000
" summit and western slope of Bergen Hill	67,000
" uplands, west of Bergen Hill	7,000
Population of entire County (1875)	163,000

DRAINAGE CONDITIONS.

The principal facts to be taken into the account of sanitary drainage, in addition to those of surface geology, area, elevation, and contour, relate to the number and density of the local population, the rain-fall, the artificial distribution of water for domestic and other uses, the natural advantages of slope and access to tide water for carrying off surplus moisture and liquid refuse, and the extent and efficiency of existing sewerage works. A synopsis of this class of information for the towns and cities of Hudson County has been compiled, and is appended to this paper for reference.

Classing the various town areas according to their physical characteristics, Harrison and Bayonne are the most favorably situated for drainage. Each of these places is situated at the southern termination of one of the two prominent ridges in the county; each has a permeable soil, regular surface slopes, and a peninsular contour which greatly extends its water front. The geological position of Bayonne is upon the trap belt, and that of Harrison upon the sandstone.

The class of wholly inland town areas contains only West

Hoboken and the Town of Union, two places which adjoin, and are upon the highest portion of the Bergen Hill trap. These places are dependent upon artificial outlets for the conveyance of their sewerage into tide-water beyond their own limits. For a portion of each town, such an outlet to the Hudson River has been made through the township of Weehawken, by the construction of a main sewer under Bull's Ferry Road, designed to receive the drainage of areas amounting to 420 acres in the three towns named. The northern portion only of West Hoboken will be drained into this sewer; the drainage of its more southerly portions must pass to the river across the marshes of Hoboken and Jersey City.

The tide marshes in the valleys of the Hackensack and Hudson present the most difficult problems in the drainage of the county. In their natural state, alluvial flats bordering upon salt water seem to form an exception, in point of salubrity, among impervious beds. In the English investigations, already quoted, the registration district which, rated by the prevalence of consumption, stood best, was one in which the greater part of the population lived on alluvium, close to the sea and at about the sea level. It is not unreasonable, therefore, to suppose that saturation of the soil by sea water, and by fresh water, are quite different in their effects, and that while the latter increases the death rate by consumption, the former is comparatively harmless, or perhaps even beneficial.

The subject of tide marshes and embanked meadows has been fully treated in the geological reports of this State; it appears from these that the materials found in the examination of the New Jersey marshes are distinct in character. They are as follows: 1st. *Blue mud*, a deposit of clayey substance, blue when wet, and gray when dry, or after exposure to the weather; 2d. *Black mud*, or disintegrated vegetable matter; 3d. *Turf*, or the fibrous and peaty matter that constitutes the spongy part of the marsh. In most of the marshes, continues the same authority, the blue mud rests upon the peaty mud. As long as tide marshes are open, liable to be overflowed at high water and soaked to their fullest capacity, they remain nearly at the level of high tide; but after banking and draining, they become quite dry. The spongy mass then slowly decays, and is consolidated, thereby causing a sinking of the whole surface. After a long series of years of cropping, the meadow settles down to low water mark, and further cultivation, on account of imperfect drainage, if, as in this country, sluices alone are used, becomes unprofitable. In some exceptional cases this result has not been reached in seventy years: the remedy resorted to in New Jersey, on the sides of fresh-water rivers, consists in opening the sluices to allow the tides to enter freely during the winter, or in some cases, for years. Another cause of this subsidence is found in the shrinkage of the peaty substratum; as observed in England, the drainage of Whittlesea Mere produced a change of level of seven feet in eighteen years after the introduction of drainage by pumping, and, under the same conditions, old drained lands were found to settle at the rate of one inch per year; this was with the drainage water not more than three feet below the surface of the meadow or reclaimed land.

The marsh, or lagoon, lying at the foot of Bergen Hill, and almost equally divided, as to its length and area, by the boundary between Hoboken and Jersey City, occupies here the place of first interest and importance. The tides have been so far excluded from some sections of this marsh as to permit of its inhabitation by upward of 20,000 persons; about three-fourths of the entire area is uninhabited and unimproved. In its present situation, the partially reclaimed district suffers from a combination of unfavorable drainage conditions.

The largest inhabited tract upon this marsh is in Hoboken, and previous to the advent of a city population was for many years an embanked meadow—its surface having been then lowered by drainage to its present level, which is about two feet below the plane of ordinary high-tide. The Harsimus division of the marsh, extending from the Hoboken boundary south to the embankment of the New Jersey railroad, is also irregularly populated. A third, and the most southerly division, which may be called the Mill Creek division, has not been at all reclaimed. In their primitive condition, the marshes were intersected by tide-water creeks which alternately conveyed sea-water to their whole area, and drained them of rain and surface water. By the formation of railways and street embankments, these natural channels have been largely closed or filled up—the Hoboken and Harsimus creeks having been thus closed, and replaced, as to their office of drainage, by tidal sewers connecting their respective divisions of the marsh with the river.

The Jersey City tidal sewers perform the usual office of sewers in the built-up streets between the marsh and the river, and, in a single case, by means of a temporary structure crossing the marsh, receive the contents of a sewer from the slope of Bergen Hill. These tidal sewers do not afford a passage for the admission upon the marsh of any but extreme or unusual tides, and they serve as a tardy means of relief in the event of inundations from rain and upland waters. The Hoboken tidal sewers are, necessarily, little more than appurtenances to the sluices placed at their outlets. The Mill Creek division of the marsh is in unrestricted communication with tide-water by the open channel of the creek, which is also a receptacle for the sewerage of the adjacent eastern slope of Bergen Hill. This is the only section of the marsh which is fully saturated with sea-water.

LOW-LEVEL AND INTERCEPTING SEWERS.

The deficiencies of the tidal system of sewers in the lower portions of Hoboken and Jersey City have elicited very serious complaints, and as public attention, more especially in the former place, has been directed to plans for the amendment of the lowland drainage, the conclusion of this paper will be allotted to a fuller notice of the conditions to which the drainage of this part of the county is subject, and by conforming to which it may be permanently improved.

Prior to the year 1870 the sewerage of this part of Hudson County, so far as it had then been undertaken, was controlled by the four local governments of Hoboken, Jersey City, Hudson City, and Bergen, each of which was acting upon its own plan of public drainage. The two towns occupying high ground made no provision for the conveyance of their drainage waters or sewerage into the rivers beyond their own boundaries, nor did the lower lying towns as it regarded themselves give attention, in the construction of their sewers to the necessity of providing for the passage through them, of a certain quantity of the upland drainage.

The tidal sewers of Jersey City were built with a view of draining, with the least practicable inclination, its former estimated area of 1,154 acres, of which only 500 acres in extent was taken to be upland, rising above the level of high water, and upon which the highest elevation was but 21 feet above tide. By the plan of sewerage drawn up and adopted in the year 1853, the levels of the sewers were so arranged as to drain the marsh at the back of the town to about the level of high water: a fall of four feet was given to every sewer in its whole length of about one mile. The sewers were placed in parallel streets, the direction being at right angles to the water front on the Hudson River, the outlets into which were placed 5½ feet below ordinary high water, measured to the floor, or invert, of the sewer. A prominent feature of the plan was a provision for thorough and frequent flushing with salt water, which was to be turned into the heads of the sewers at the lowest stage of tide in the river; this part of the plan has not been put into systematic use in any of the various forms in which it is practicable. The plan also involved, as a necessary but difficult condition, the filling up and permanent regulation of the streets upon the marsh area to a height of six feet above the natural level of the surface.

This plan of sewerage has failed to efficiently drain the limited district for which alone it was designed; a working system of sewers can only be constructed after the boundaries of a natural drainage area have been defined, when the situation and direction of the natural drainage valleys having been determined, the lines of the main or receiving sewers must be placed in them, and at such a depth as shall control the underground waters by means of an arterial system extending to every part of the tributary area. As an illustration, the Southern Low-Level Sewer in London, 10 miles in length, on the south side of the Thames, which was completed and brought into use in 1864, does not follow the course of that river, but commencing at its upper end at a point on its bank, takes a more direct line through low ground, following an ancient river bed. The surface of the drained area has an extent of 20 square miles and is mostly below the level of high tide, having been formerly covered with water to the depth, in many places, of 5 or 6 feet.

The sewers throughout the district were tide-locked, stagnant, and frequently overcharged, and the cellars and basements of houses flooded, after long-continued rain. The direction given to the sewer carried it about one and one-half mile inland from the river; and it is constructed for its whole length in a stratum of sand and gravel overlying clay, and copiously charged with water. Its size increases from a sewer of four feet in diameter at its beginning, to the dimensions of a double culvert, each part of which is 7 by 7 feet at its lower termination, where it delivers its contents to be lifted by powerful pumping machinery into the Southern Outfall Sewer. At this point the bottom of the sewer is 12 feet below low-water, and 30 feet below high-water mark; its fall ranges from four feet to two feet per mile in its different divisions.

By the construction of the low-level outlet a constant flow has been established in the tide-locked sewers; the level of the ground water has been very much lowered, and places so low as to require embankment from the Thames are now thoroughly drained. The effect is equivalent to that of raising the whole surface of the ground a height of 20 feet. Means exist of introducing fresh water into the net-work of sewers at twenty or more places on the Thames, and so thoroughly can these sewers now be flushed in this way, that it is almost impossible that deposit of either hard or soft substances can take place in them. The main sewer is cleansed with equal facility and in the same way, by sending through it a stream of water from the river, ample for that purpose.

The total amount paid for the construction of the Southern Low-Level Sewer, with its special works, including a number of important tunnels under creeks, canals, railways, and houses, as taken from the official statement of the Metropolitan Board of Works, gives an average cost of $27.50 per lineal foot. The cost of erecting the pumping works, including four steam pumping engines of the united capacity of 600,000 cubic feet of water per hour lifted 18 feet high, was $570,000, exclusive of the cost of land.

It was foreseen in the origination of the plans, that it would be impossible to secure the looked-for results from the construction of the low-level sewer—the maintenance of a free and constant flow in the original sewers, together with a full control of the tributary drainage above and below ground—without a resort to the method of pumping; and that the success of the system adopted would depend upon so dealing with the drainage and sewerage waters of an area of 20 square miles of high ground, constituting the rim of the drainage basin, as to carry them off, to the largest possible extent, by gravitation alone through an entirely distinct channel, or High-Level Intercepting Sewer.

In the same way the drainage and sewerage waters of the high ground on Bergen Hill, which must find their way across, or through, the Hoboken and Jersey City marshes to the Hudson River, are capable of being separately and conveniently disposed of, if collected at two or three points at the foot of the eastern slope of the hill, to which they might be brought in converging lines of cast-iron pipes, the contents of which should then be passed on through the intervening low grounds to corresponding district outfalls on the river front, in tight conduits of the same description, adapted to sustain the head or pressure due to the height of the intake; the full head to be thus rendered available, as required, for the production of a current proportioned to the greatest or least flow to be anticipated. The introduction of this drainage into the lower or tidal system of sewers, is as objectionable and injudicious here as in London.

APPENDIX.

SEWERAGE SYSTEMS OF LARGE CITIES.

Hamburg was the first city which had a complete systematic sewerage system throughout, according to modern ideas. They were the work of Mr. Lindley, who was employed after the greater part of the city had been devastated by fire in 1842, to lay out anew the burnt portion and devise a system of sewerage for the whole city. How far that was in advance of the rest of the world, when the work was undertaken, may be inferred from the fact that there are no real advances in new principles from that time up to the present day. The sewers are made on the " open system," that is, the rain-water spouts are all untrapped to serve as ventilators to the sewers; the street-gullies are also without traps, and there are gratings for ventilation opening into the street. It is very rare that any of the latter are sources of complaint, inasmuch as the sewers are kept so clean that there are seldom any foul-smelling gases.

The great feature in Hamburg, however, is the weekly flushing at low tide by letting the waters of the Binnen Alster flow through the sewers with great force. There are also flushing-gates for washing out the branch sewers. This whole process is carried out so completely that the siphon under the river Alster has not required cleaning since it was built, in 1845.

Twenty-five years after the sewers were completed, they were found by a commission of experts to be clean and almost without odor.

The surface water from streets is let into the sewers through grated gullies, placed about 40 yards apart. These have neither traps nor catch basins, and consequently serve as ventilators to the sewers.

Frankfort-on-the-Main.—A new system of sewers was begun in 1867, under the same distinguished English engineer, Mr. W. Lindley. The old sewers are to be filled up and destroyed. The plans show the highest skill. The mechanical execution is most admirable, and no other large city in Europe is so perfectly sewered. The sewage is discharged in the middle of the river Main, under water, and at some distance below the city. The sewers are put at great depth in order to drain the soil, and to take advantage of the ground water for flushing. The street-gullies are all trapped, and no dust or sand is allowed to get in from that source.

Flushing is secured by means of three hundred flushing-gates in the course of the sewers, which are closed long enough to get sufficient head, and then suddenly opened. Ventilation is to be got by soil-pipes carried through the roofs, by rain-water pipes, and by three high ventilating towers, one of which is the chimney of a manufactory. The river is so broad and rapid that it is not likely to be seriously contaminated for some years.

Brooklyn has very finely constructed sewers, on an excellent system. The outlets have been located with reference to avoiding a nuisance (not in all cases with entire success), and there is very little complaint against them. It is one of the few cities in this country where free ventilation is got by openings into the streets. Many of these gratings were examined, and there were only a few where any smell could be detected six feet from the surface of the streets. There is very seldom any complaint of them, and very many people fail to discover that they exist at all.

Washington.—Here enormous main sewers are building in the courses of the natural streams, the outlets to be at deep water instead of being on the flats, as at present. This plan has some advantages in draining the soil, as natural drainage-areas are followed; but they are much more than counterbalanced by having the sewers pass across house-lots, through cellars, etc., so as to be difficult of access for repairs, and to contaminate the air of houses in case of accident. In case of excessive rain, too, it is generally difficult to prevent their being filled to overflowing.

London.—When water-closets were first introduced in this city, about the beginning of the present century, they were connected with the sewers. The latter were large and badly constructed; and the pollution of the soil became so great that a law was passed forbidding their use as a means of discharge for the water-closets or privies. Sess-pools were then built all over the city, and the nuisance so increased that another law was passed, in 1847, requiring that they should be abolished, and that connections should in all cases be made with the sewers.

The contamination of the soil from these various sources became so great, that in 1866, during the cholera epidemic, posters were placed upon all the city pumps, stating that the water was none of it fit for drinking purposes. Even at the present day cases of illness are not unfrequently traced to buried and forgotten sess-pools, and many polluted wells are still in use.

In 1856 the stench from the discharge of sewage into the Thames had become intolerable; there had been two recent epidemics of cholera in the city (in 1849 and 1854), and the many evils in the sewerage system had become so great, that engineers and physicians had united in declaring the necessity of a change. As a consequence, the main-drainage scheme was adopted, consisting of five sets of intercepting sewers, with four pumping stations.

The two outlets for the northern and southern sections of the metropolis are at Barking and at Crossness, respectively ten and fourteen miles below the city proper; and they are covered by the water at the time of discharge. At each outlet there is a reservoir capable of containing the ordinary sewage of twenty-four hours, if necessary. The discharge into the river from these reservoirs takes place only during the two hours succeeding high water, so that an abundance of time is given for the ebb-tide to carry all the sewage to a safe distance.

In the City of London proper, where the land is quite high, the sewers are well flushed, and they are ventilated by gratings placed at intervals from one hundred feet to fifty yards apart, opening directly into the streets. Where the sewer-gases are especially foul, they pass first through charcoal filters. Ventilation is also got in the different parishes by extending the soil-pipes through the roofs, by special pipes carried up above the tops of the houses, and in some cases by connecting rain-water spouts with the sewers without traps.

The sewers of the main-drainage scheme are self-flushing, and are a perfect success; and the pumps work admirably, so that places so low that they must be protected from the Thames by embankments are thoroughly drained.

Many of the old sewers, however, especially where the sand and dirt from the streets are discharged directly into them, require cleaning from time to time. This is done by contract, and inspections are made every three months by the Sewer Department to see that it is properly done. They are also flushed by gates which hold the water back until the sewers are nearly full, and then, being suddenly opened, let it go with a rush.

Since the intercepting sewers were built, the level of the ground-water has been very much lowered, cellars formerly wet have become dry, and, in some few places, trees are even dying from loss of moisture in the soil.

The storm-water is discharged into the Thames by overflows. some of which are so low that they are tide-locked at high water, Consequently, in case of very heavy rain at high tide, which indeed does not often happen, those cellars which are placed below the grade established by the city authorities are liable to be flooded. This difficulty, however, has been obviated for a great part of the city by means of a sewer for surface water only.

Three of the pumping-stations of London, and those of Stratford, Birmingham, Paris, Dantzic, Bedford, Crewe, and Leeds having been visited, were found invariably to be free from offensive odors outside of the buildings containing the pumps. In most cases, too, the odor was only very slight within the buildings.

Boston.—A plan for an improved system of sewerage, or main drainage, the cost of which it is estimated will be four million dollars, has been undertaken during the year 1877, under the advice of the most expert specialist in this department of engineering in the United States.

As the borders of the sewered portions of Boston consist largely of broad strips of made land, filled to level planes only six or eight feet above mean high-tide, the sewers are necessarily built with slight grades, and are so situated as to be tide-locked a large portion of the time. In the existing system the sewage is discharged through some seventy different outlets along the shore lines of the city, and a number of these outlets may said to be in the very heart of the city. The discharge takes place during the latter part of the ebb and the first of the flood tide, so that the sewage, instead of being swept out into the harbor and there diffused, is carried inland, and such portion as will deposit in still water is thrown down at the turn of the tide upon the broad flats that exist within and around the city. This intermittent discharge produces other serious evils. During the time the sewage is accumulating in the sewers there is very little current in them, and, in consequence, deposits are formed which are not readily removed, and which, when putrefaction begins, are the source of dangerous gases. Again; as the sewage accumulates and rises in the sewers the gases are compressed, and, since adequate ventilation is not provided, are liable to be forced through the house drains into the houses.

The more important objects, then, to be attained by the improved system of sewerage, are an uninterrupted removal of all sewage matter from the vicinity of the inhabited districts, and a discharge of this matter at such point or points, and under such conditions, that it shall not be brought back to be thrown down upon the adjacent shores.

The features of the plan adopted are as follows: a system of intercepting low-level sewers along the margin of the city, to receive the flow of the existing sewers; a main sewer into which the former empty, and which crossing the city leads to a pumping station, where, by pumping machinery the sewage matter will be lifted about thirty feet; an outfall sewer leading from the pumps to a reservoir situated at some favorable point for discharge, and from which the sewage, having accumulated during the latter part of the ebb and the whole of the flood tide, is to be let out into the harbor during the first two or three hours of the ebb.

Though not an integral part of the plan as recommended for present adoption, the engineers assume that at some future day a system of *high-level* intercepting sewers will be added, which will conduct to the outfall all sewage that can be delivered at the reservoir without pumping.

Underground Water in relation to Sewer Channels and Tide, at Boston.

Experiments made with pipes driven into the ground in various parts of Boston between the months of July and November, 1875, showed that the water in the soil of the flat parts of the city stood at a level of from six and one half to eight feet below the surface of the streets, and very often above the centre of the sewer.

On the high land, where the soil was loose and porous, the water stood much lower; with a clay subsoil near the surface, however, the soil is much more moist, especially at the foot of the hill, where the surface drainage of the higher land is more or less collected.

In all the "made land" the level of the ground water was found to rise some inches at high tide, showing that any drainage from the soil into the sewers was checked or reversed at that time. At one place of observation this rise of the water amounted to one foot, and in another part of the city, to three feet. The general conclusion from these experiments was that "soil-mixture" was a serious evil in all the low part of the city.

Another conclusion which was reached, was that while the proposed system of low-level intercepting sewers and pumping works, would lower the level of the ground water in these portions of the city several feet, it was not to be expected that it could be reduced much below the plane of mean low-tide in the harbor unless the city were surrounded by a water-tight dike.

It should be stated in explanation, also, that the mean range of tide at Boston is 9.8 feet. A selection from the recorded experiments is presented in the following table; further details are not given.

Results of experiments on the drainage-level in sewered ground at Boston.

STATIONS.	Elevations, in feet, referred to Mean High Water. + above. — below.			Depths, in feet, from the street surface at the station.		Difference in height between the level of the underground water and the bottom of the sewer channel.	Additional difference, being the extreme rise observed after heavy rains.
	Of the street surface.	Of the average level of the underground water.	Of the bottom of the channel of the sewer.	To the underground water.	To the channel of the sewer.		
D.	+3.45	—3.05	—4.3	6.5	7.75	1.25	1.5
C.	+4.95	—2.3	—3.8	7.25	8.75	1.5	0.5
I.	+3 7	—3.8	—7.8	7.5	11.5	4.0	1.5
E.	+4.7	—2.3	—6.3	7 0	11.0	4.0	1.0
F.	+5.2	—1.8	—6.6	7.0	11.75	4.75	1.25
G.	+5.7	—1.3	—2.8	7.0	8.5	1.5	1.25
N.	+6.7	—1.3	—7.3	8.0	14.0	6.0	1.0
P.	+7.2	—0.3	—2.8	7.5	10.0	2.5	3.5
B.	+7.2	+0.2	—4.8	7.0	12.0	5.0	2 5
A.	+36.7	+30.2	+26.7	6.5	10.0	3.5	1.5

Points of Comparison between the Drainage Conditions of the described Areas in London and Jersey City.

(Hoboken included in Jersey City Area.)

LONDON AREA.

Area of high district........................20 sq. miles.

Greatest elevation in high district, above tide...350 feet.

Area of low district........................20 sq. miles.

Least elevation in low district, referred to plane of high tide..................................6 ft. below.

Range of tide (average)........................18.3 feet.

Length of low-level district........................10 miles.

Average breadth of ditto........................2 miles.

Character of substratum in the line of lowest ground :
Open gravel and sand, averaging 30 feet in depth, overlying clay.

Subsoil water in the lowest ground :
Exclusively fresh.

JERSEY CITY AREA.

Area of high district........................2 sq. miles.

viz.:	ACRES.
On Bergen Hill, from Communipaw north, in Jersey City..................	900
In West Hoboken........................	250
Castle Point, Hoboken..................	130
Total....	1,280

Greatest elevation in high district, above tide...250 feet.

Area of low district........................3 sq. miles.

viz.:	ACRES.
Slope of Bergen Hill, estimated...........	120
Marsh adjacent to ditto...................	850
Slope of Hoboken upland, estimated......	150
Jersey City, east of the marsh, estimated..	800
Total....	1,920

Least elevation in low district, referred to plane of high tide..................................2 ft. below

Range of tide (average)........................4.4 feet.

Length of low-level district ....3.5 miles.

Average breadth of ditto........................0.9 mile.

Character of substratum in the line of lowest ground :
Peat, mud, and soft clay, estimated to average 50 feet in depth, overlying rock.

Subsoil water in the lowest ground :
Salt, in natural marsh; brackish, in sunken, embanked meadow; less brackish, where marsh has been filled to above tide.*

* The quantity of Passaic water annually supplied to houses and small takers in Jersey City and Hoboken, is sufficient to cover the whole area embraced in the pipe system to a depth of 60 inches. The average depth of the annual rain-fall in this county is 46 inches, of which from one-third to one-half enters into the subsoil water, after deducting the fixed losses by evaporation and the variable element of surface drainage on the natural ground.

Condensed Statement of Area, Population, Soil, and Drainage Data of the Towns and Cities in Hudson County.

NAME OF PLACE.	AREA. — DESCRIPTION OF SURFACE.	ELEVATIONS, ON CREST OF WATERSHED. — CHARACTER OF SUBSTRATUM.	POPULATION, 1875. AREA INHABITED, OR BUILT UP.	EXTENT, ETC., OF WATER-FRONT.	ADDITIONAL MEMORANDA.
HARRISON.	Total area: 760 acres. Upland,500 acres; sloping to marsh. Riparian marsh, estimated at 250 acres.	Elevation, 50 ft. Deep bed of gravel overlying sandstone. Peat overlying same.	Population, 4,765, on about 100 acres.	2.3 miles, on Passaic River.	A number of streets opened and built upon; one sewer (2,250 feet); no public water supply.
KEARNEY.	Total area: 6,400 acres. High ground, bordering the Passaic River. Marsh bordering the Passaic and Hackensack Rivers.	Elevation, 50 to 150 ft. Sandstone, with stratum of light soil. Same overlaid by 30 to 90 ft. of soft clay and mud, covered by peat.	Population, 1,401, on about 3 sq miles of upland.	West, 2.6 miles on Passaic River. South, 2.6 miles on same. East, 5.2 miles on Hackensack River.	High ground near the Passaic, occupied by cottages and villas. Hackensack marshes are here embanked from tide, and partially reclaimed.
NORTH BERGEN.	Total area: 6,800 acres. Secaucus upland, 1.8 sq mile. Bergen Ridge, 3.1 sq. miles. Marsh touching Hackensack River; maximum depth, 90 feet.	Elevation of Secaucus Ridge, 25 to 30 ft. (sandstone). Elevation of Snake Hill, 175 feet (trap). Elevat'n Bergen Ridge, 225 to 260 ft. (trap); summit tenacious soil; gravel slope toward west.	Population, 3,928, on 5 square miles of upland.	West, 7 miles on Hackensack River. East, 0.7 mile on Hudson River.	Uplands used in agriculture; marshes subject to overflow.
UNION (TOWNSHIP).	Total area: 835 acres. Rocky upland (1 sq. m.) from the summit to east face of Palisades. Talus terminating in alluvium.	Elevation of Bergen Ridge, 220 to 260 feet. Slope from elevation of 150 feet at face of Palisades, extending 1,000 ft. to edge of river.	Population, 2,580 (scattered), on 100 acres.	1 mile, on Hudson River.	Unimproved territory. A few streets graded on upland. Stock yards at river front.
WEEHAWKEN.	Total area: 400 acres. Rocky upland, spur of Bergen Ridge. Marsh on water-front.	Elevation of summit, 180 feet (trap). Slopes east and west.	Population, 602 (scattered).	1.8 mile, on Hudson River.	Upland, in private grounds. Coal and oil depots at river. Bull's Ferry Road sewer, 4,500 ft. (as now built), will drain 100 acres.
TOWN OF UNION.	Total area: 275 acres. On Bergen Ridge, with general eastward slope. Undrained basin of 100 acres, built upon.	Elevation, 170 to 190 ft. Retentive earth overlying trap.	Population, 4,676, on 175 acres.	No water-front.	Town population. No public water supply. Bull's Ferry Road main sewer skirts eastern edge of town (2,250 feet), and will drain 112 acres. No other sewer.
WEST HOBOKEN	Total area: 520 acres. Upland, adjoining, and similar to last.	Elevation, 160 to 250 ft. Substratum and soil same as last.	Population, 5,219 (scattered), on whole area.	No water-front.	As to population, water supply, and sewers, same as last. Has right to carry the drainage of 208 acres into Bull's Ferry Road sewer. Drainage of 70 acres escapes to westward.
HOBOKEN.	Total area: 720 acres. Upland (270 acres) at river, slopes westward to marsh. Marsh area, 450 acres.	Elevation, 100 feet. Serpentine and quartzite. Clay, mud, and peat (20 to 100 feet deep).	Population, 24,766, on 90 acres of upland and marsh area of 140 acres.	1.7 mile, on Hudson River.	City population. Abundant water supply. Efficient sewerage on 90 acres of populated upland. Marshes embanked from tide, and now, in southern portion, two feet below level of high water.
JERSEY CITY.	Total area: 8,000 acres. Bergen Ridge, about 4,400 acres. Marsh, west side, about 1,500 acres. Marsh, east side, about 700 acres. Firm, natural, and made ground on eastern water-front, about 1,400 acres.	Elevation, 60 to 160 ft. Trap; summit covered with tenacious earth; slopes (east and west) composed of more porous material. Detached upland, argillaceous sand. Marsh, same as described above	Total population, 109,227. On Bergen Hill, 44,000. On Lowlands, 65,000.	2 miles on Hudson River. 6 miles on New York Bay. 5 miles on Hackensack River.	Streets opened very generally on all upland, north of the Greenville addition. Abundant water supply over a high district of two square miles on Bergen Ridge, and an area of one square mile of lowlands east of Ridge. Tolerable sewerage in portions of the high district, but wanting efficient connection with tide water. A distinct system of tidal sewers, and a city population, in the lower water district.
BAYONNE.	Total area: 2,500 acres. Upland of Bergen Neck about 1,800 acres. Upland of Constable's Hook, about 200 acres. Adjacent marsh about 450 acres.	Elevation, 20 to 40 feet. Trap, with occasional sandstone; friable soil. Detached upland, and marsh, same as at Jersey City.	Population, 5,836, centred at various points.	2½ miles on New York Bay. 3 miles on Kill Van Kull. 5 miles on Newark Bay.	Suburban population. No public water supply. Streets opened throughout the length of the district. About 280 acres are now drained by five miles of public sewers.